

Radiative heating and cloud water structures related to boreal summer intraseasonal oscillation (BSISO): Observations and process-oriented GCM evaluations

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The boreal summer intraseasonal oscillation (BSISO) is a tropical intraseasonal variability (30-60 days) most active in summer. BSISO shows pronounced meridional propagation from the equator towards the Indian continent and is closely related to the active/break phases of the Asian summer monsoon rainfall. Previous studies showed that BSISO provides a primary source of monsoon predictability. Because of its closely relationship to the Asian Monsoon precipitation variabilities of sub-seasonal time scales, BSISO has been a topic of intense study in earlier studies. Webster et al. (1998) and Goswami and Mohan (2001), for example, showed that strong/weak BSISO is related to drier/wetter monsoon rainfall in India. Jiang et al. (2011) showed that the meridional-vertical structures of the BSISO-related anomalous cloud water contents and circulation resemble closely typical tropical convective systems. This study aims to expand previous BSISO-related studies by analyzing the structures of anomalous cloud water contents and radiative heating associated with northward propagating BSISO for the period 2006-10 using satellite data and the ERA-Interim reanalysis. Accurate simulations of the boreal summer intraseasonal variations (BSISV) of tropical rainfall can be closely related with GCMs' capability for extended-range forecasting of the Asian summer monsoon rainfall. Thus, it is of a practical interest to evaluate the BSISV characteristics simulated in GCMs. The cloud water content and radiative heating rate structures obtained from the observed data are then used to examine the relationship between the GCM skill in simulating northward propagation of BSISOs and that in simulating the structures of cloud water/radiative heating anomalies.

Based on the TRMM7 daily precipitation, 17 Strong northward propagating BSISV events are identified for the 5-year period 2006-10, with nearly the same northward propagating features as in Jiang et al. (2011). The latitude-height structure of the composite liquid and ice cloud water content anomalies for the 2008-10 in this study is nearly identical to that for the 2006-08 period in the Jiang et al. (2011) study. The latitude-height structure of the composite radiative heating anomalies are characterized by: (1) Positive (negative) SW heating anomaly maximum in the upper troposphere, approximately in the location of the positive IWC concentration maxima (low troposphere), (2) Shallow LW cooling anomaly in the upper troposphere at 200hPa, and (3) LW heating anomaly maxima in the lower troposphere. The positive SW heating anomaly in the upper troposphere indicate enhanced absorption of insolation by increased ice clouds in the upper troposphere. The negative SW heating anomaly in the lower troposphere may result from shading of enhanced upper tropospheric ice clouds and lower tropospheric liquid clouds. The positive LW heating in the lower troposphere may result from the enhanced downward LW fluxes from the positive anomalies of the upper tropospheric IWC and the LWC anomalies in the mid- and low troposphere. The net radiative heating anomalies (i.e., LW + SW heating anomalies) show a positive heating anomaly in the upper troposphere and negligible radiative heating in the low troposphere.

Using the skill score in simulating the northward propagation of the BSISO rainfall anomaly in Mani et al. (2016) as the reference, this study examines the GCM skill in simulating the

structures of the BSISO-related anomalous cloud water and radiative heating rates measured in terms of correlation coefficients between the observed and simulated spatial structures. It has been found that there exist weak-moderate but positive relationships between the model skill in simulating the northward propagation of the BSISO rainfall and the skill in simulating the structures of the BSISO-related anomalous cloud water contents and radiative heating rates. The relationship is much stronger for the radiative heating rates than cloud water; the correlations between the northward propagation skill scores and the radiative heating rate skill scores are well over 95% confidence level for the all three radiative heating rates; only the correlation between the northward propagating skill score and the ICW skill score are significant at the 95% level. The results suggest that models of higher skills in simulating the tropical convection-related structures possess higher skill in simulating the northward propagation of BSISOs. The BSISO over the subtropical East Asia may be related to summer rainfall over Korea-Japan; it needs to receive more attention.